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(54) **CLEANING BRUSH CONDITIONING APPARATUS**

(75) Inventors: **Annette M. Crevasse**, Orlando, FL (US); **William G. Easter**, Orlando, FL (US); **John A. Maze**, Orlando, FL (US); **Frank Miceli**, Orlando, FL (US)

(73) Assignee: **Agere Systems Inc.**, Allentown, PA (US)

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(52) **U.S. Cl.** **438/690**; 438/691; 438/692; 438/706; 438/745

(58) **Field of Search** 438/690, 691, 438/692, 706, 745

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,650,039	A	*	7/1997	Talieh	216/89
5,785,585	A	*	7/1998	Manfredi et al.	451/285
6,004,196	A	*	12/1999	Doan et al.	451/443
6,086,460	A	*	7/2000	Labunsky et al.	451/56
6,106,369	A	*	8/2000	Konishi et al.	451/41
6,270,396	B1	*	8/2001	Uchiyama	451/56
6,306,019	B1	*	10/2001	Finkelman	451/56
6,488,573	B1	*	12/2002	Kobayashi et al.	451/285
2002/0119613	A1	*	8/2002	Yang et al.	438/200

OTHER PUBLICATIONS

Wolf, S. and Tauber, R.N., "Silicon Processing for the VLSI Era", vol. 1, pp. 23–25.*

* cited by examiner

Primary Examiner—Benjamin L. Utech
Assistant Examiner—Vanessa Perez-Ramos

(57) **ABSTRACT**

The present invention provides a method of manufacturing an integrated circuit using a cleaning brush and a cleaning brush conditioning apparatus. In one embodiment, the cleaning brush conditioning apparatus comprises a conditioning bar and a load cell coupled to the conditioning bar. The load cell is configured to force the conditioning bar against the cleaning brush.

9 Claims, 4 Drawing Sheets

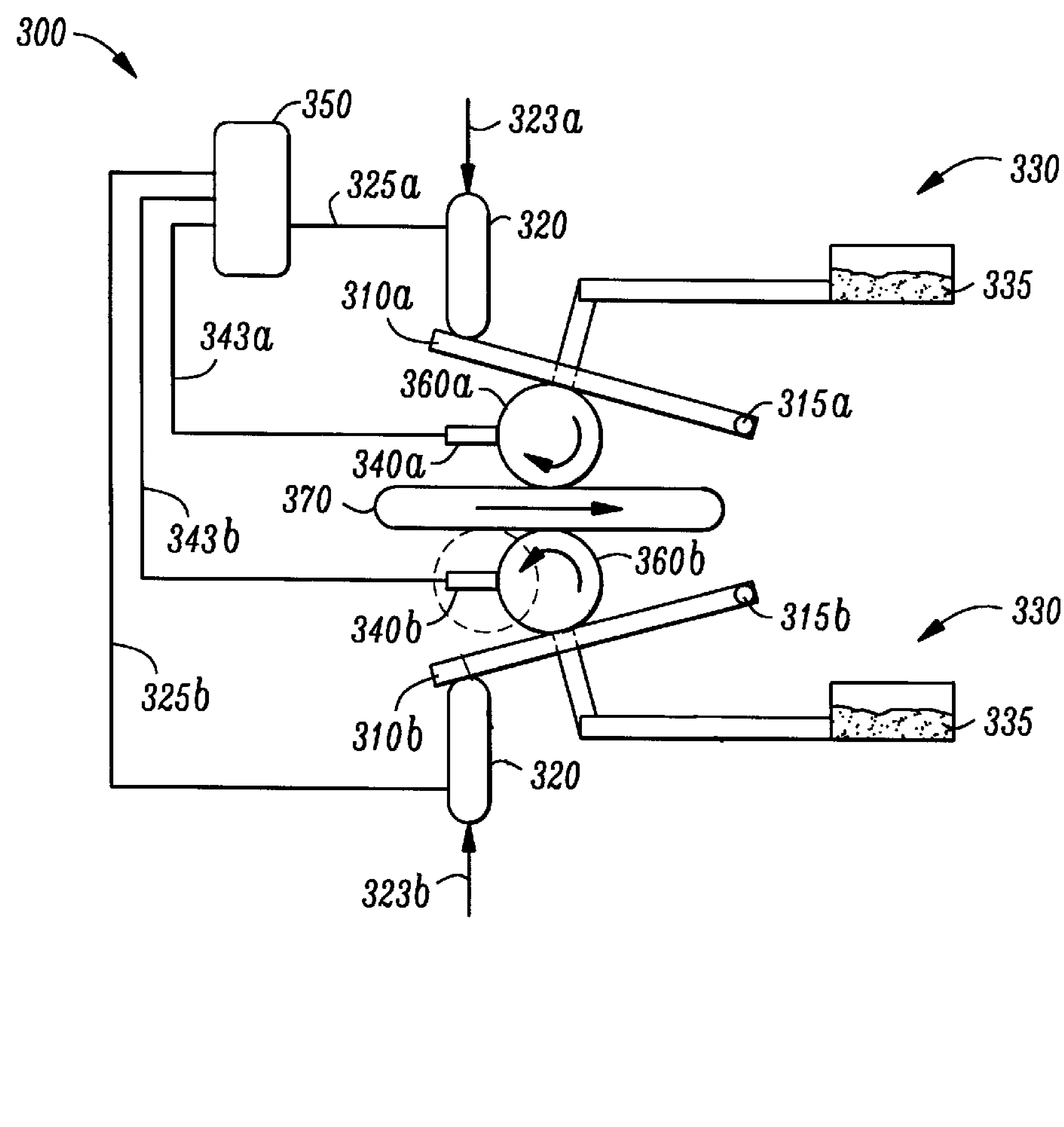
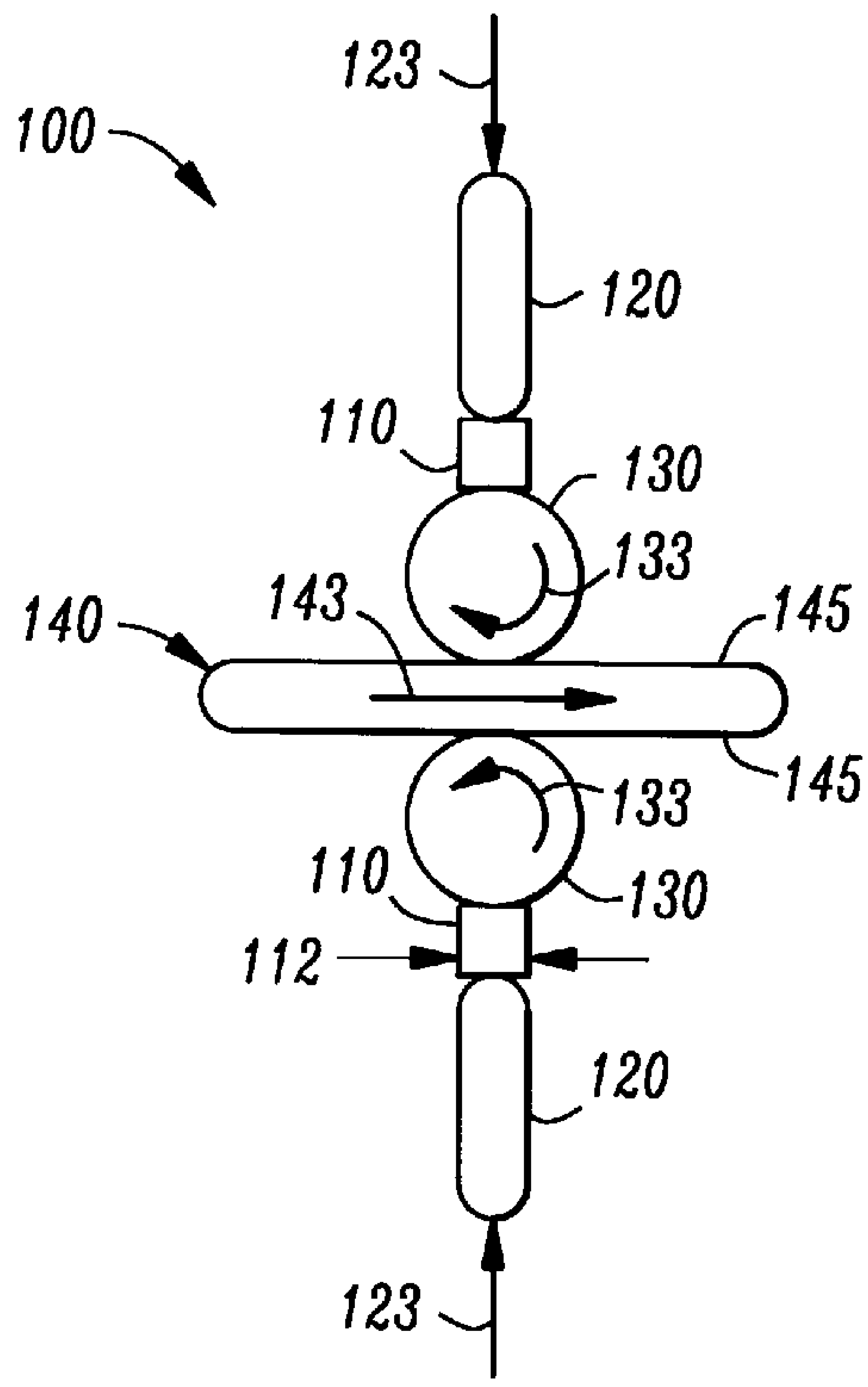


FIG. 1A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100
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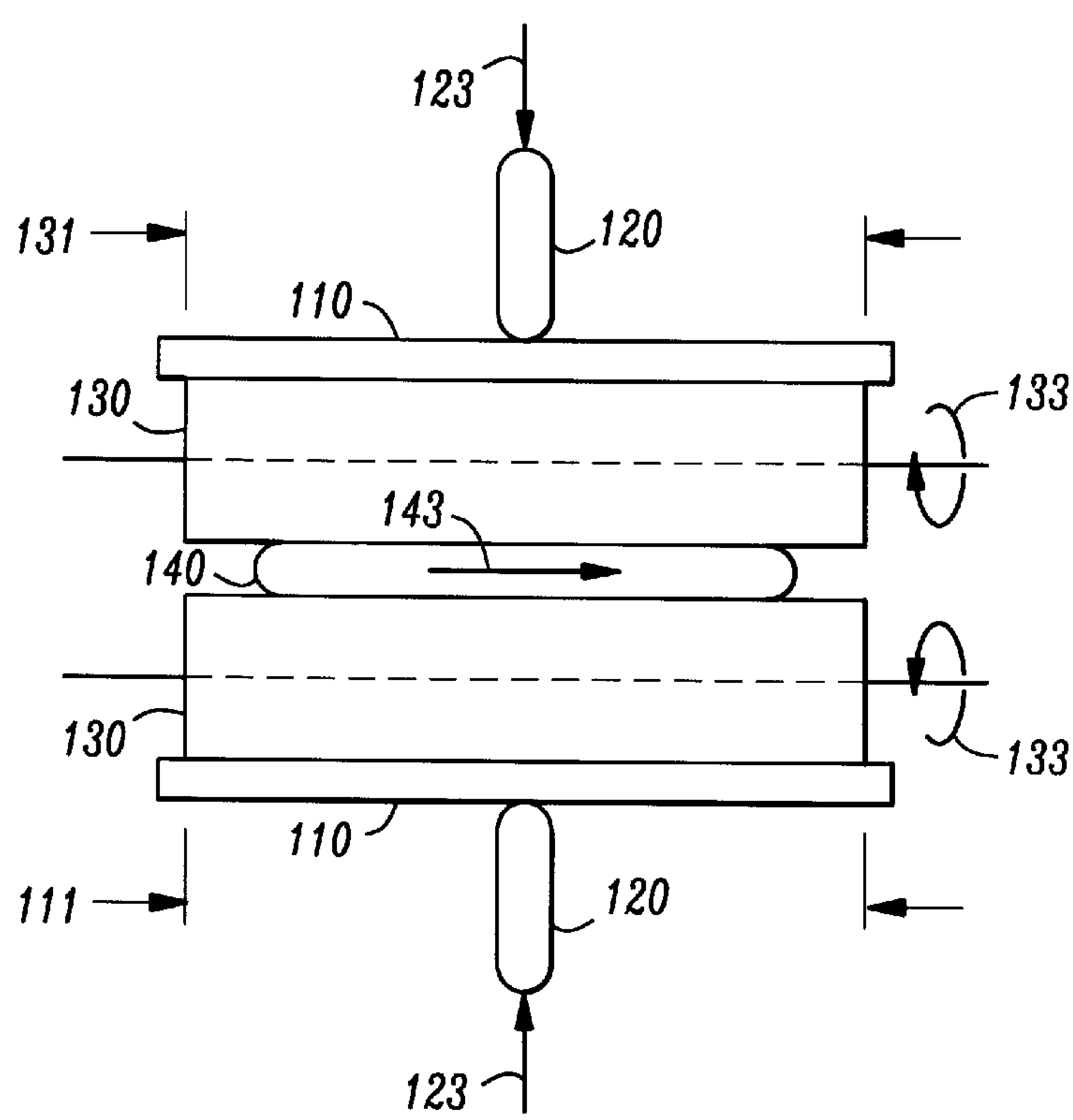
123

FIG. 1B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131
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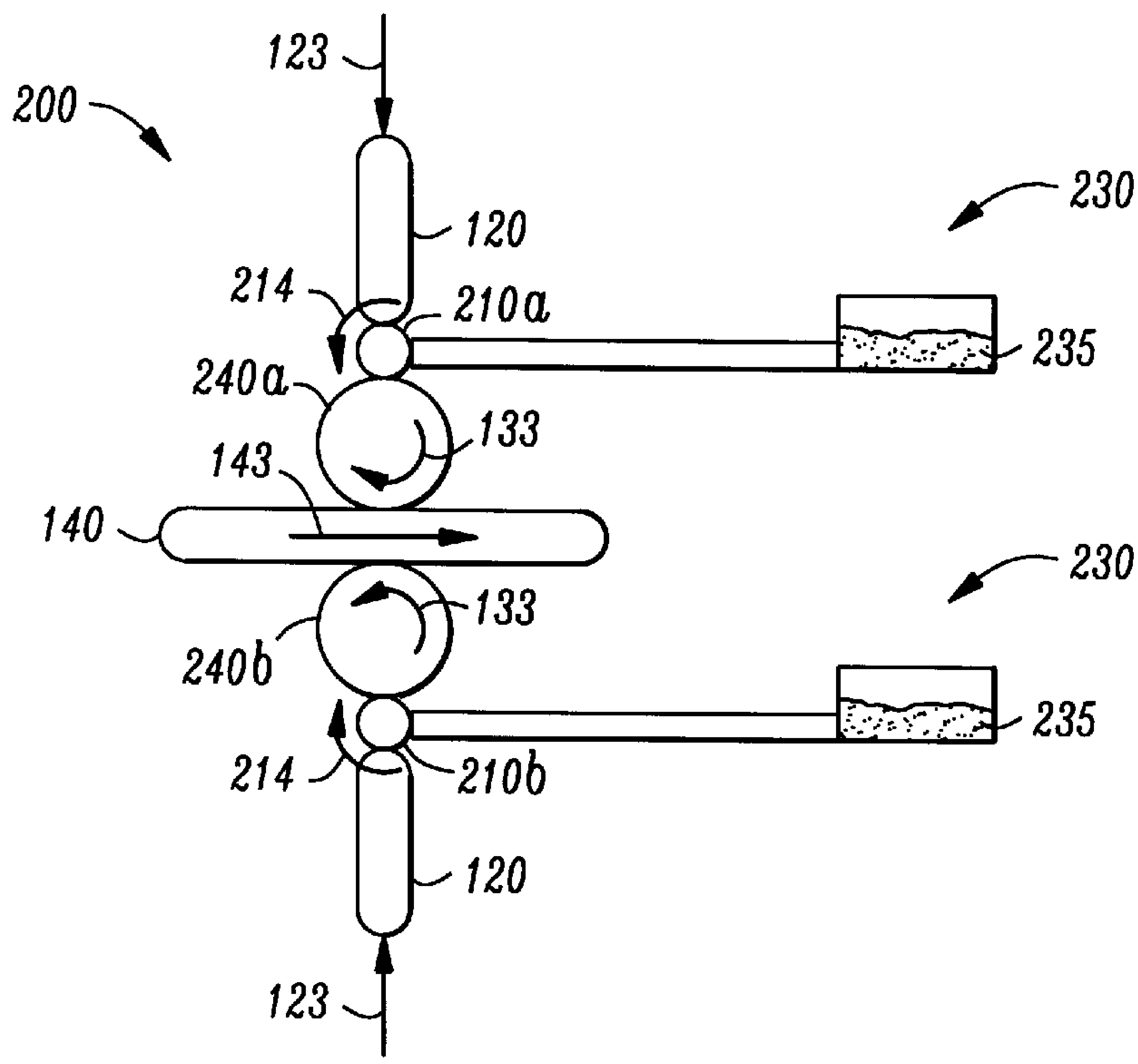
120
123

FIG. 2A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200
120
230
214
210a
240a
235
133
143
140
230
133
240b
235
214
210b
120
123

FIG. 2B

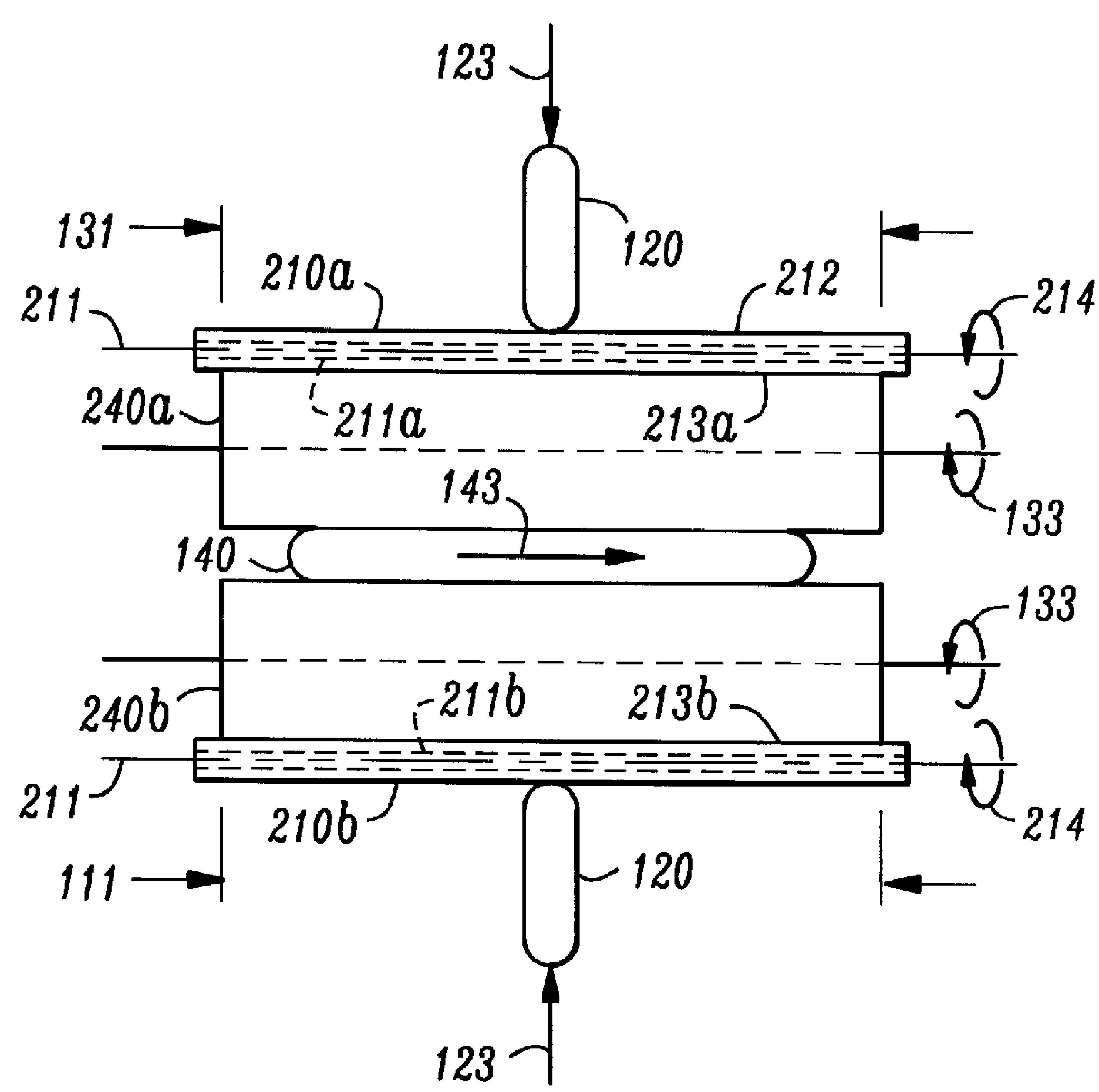
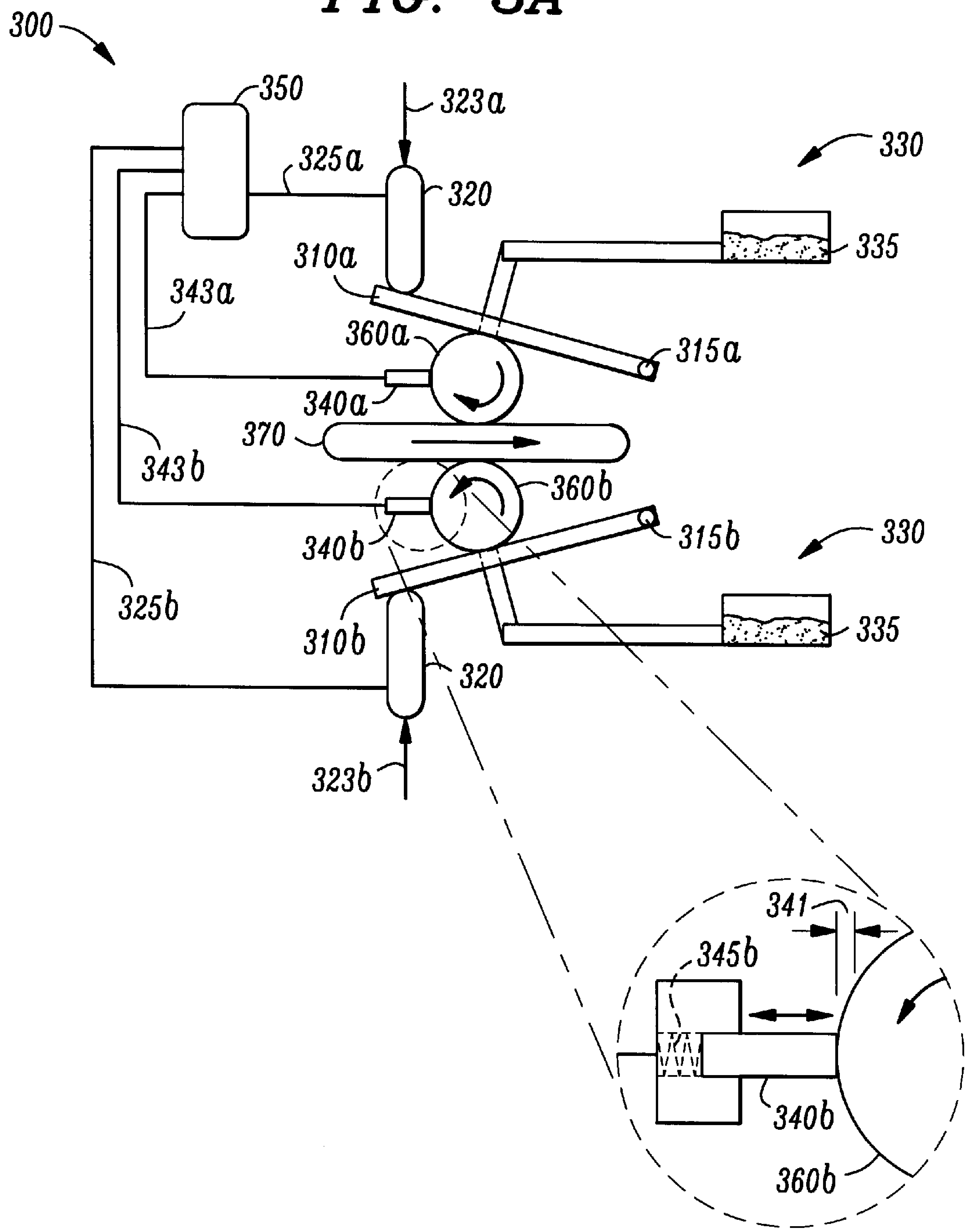

123
131
120
211
210a
212
214
240a
211a
213a
143
133
140
133
240b
211b
213b
211
210b
214
111
120
123

FIG. 3A


300
350
323a
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320
330
335
310a
343a
360a
315a
340a
370
343b
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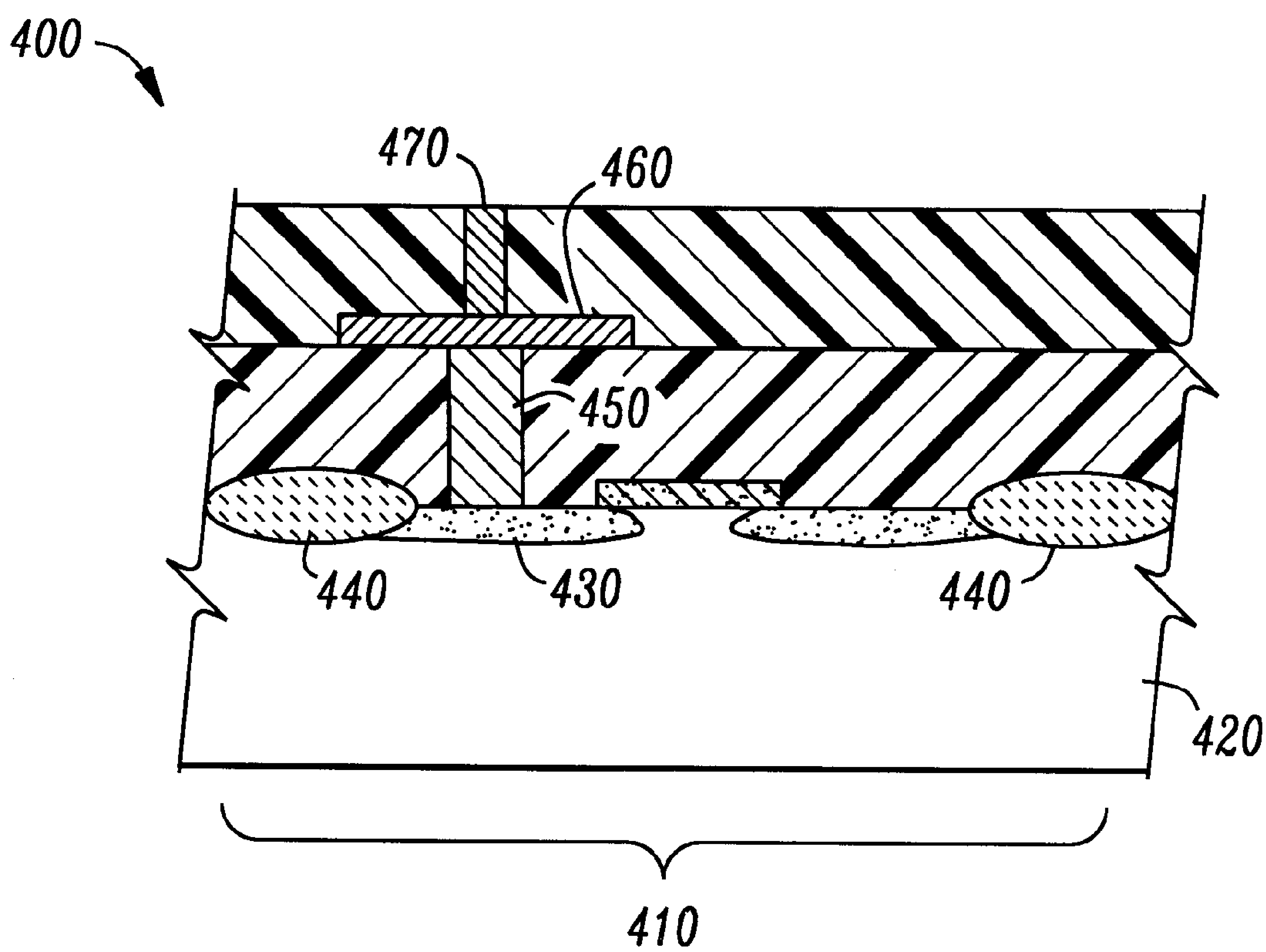
315b
330
325b
335
310b
320
323b
341
345b
340b
360b

FIG. 3B

FIG. 4



CLEANING BRUSH CONDITIONING APPARATUS

TECHNICAL FIELD OF THE INVENTION

The present invention is directed, in general, to a wafer cleaning apparatus and, more specifically, to an apparatus and method for maintaining semiconductor wafer cleaning brushes in a state of readiness for wafer cleaning.

BACKGROUND OF THE INVENTION

During semiconductor manufacturing, several processes create debris that is best removed by mechanical means, specifically, after silicon polishing, laser scribing and chemical/mechanical polishing. Silicon polishing is performed after a silicon ingot is cut into wafers to prepare the wafers for further precessing. Laser scribing is the process by which identifying numbers are scribed into the wafer, and chemical/mechanical polishing uses an abrasive slurry to planarize the wafer surface. Each of these processes creates debris that may cling to the wafer surface and present a potential contamination hazard. With the high cost of semiconductor manufacturing and intense competition among manufacturers, every effort must be made to minimize any contamination hazard.

Following these processes, the surfaces of the semiconductor wafer are best cleaned of any residual debris by passing the wafer between two rollers equipped with polyvinyl alcohol (PVA) brushes. While ammonium hydroxide or dilute hydrofluoric acid is used for semiconductor wafer cleaning the PVA brushes may also be kept wetted with de-ionized water to provide the high quality surface necessary for removing debris. While in use, the combination of brush rotation and pressure applied to the semiconductor wafer through the brushes flexes the PVA material and keeps the brushes in proper condition for cleaning additional wafers.

However, the brushes are idle when there are no wafers being cleaned and, as a consequence, the brushes lose their resilience, thereby suffering a loss of particle removal efficiency. Therefore, before the brushes may be used on production-quality wafers, "dummy" or warmup wafers, i.e., wafers that will not be used to produce commercially useable chips, are run through the cleaners to condition the PVA brushes and restore their resilience. As few as 10 percent to as many as 20 percent of the wafers in small lots passing through the cleaner may be dummy wafers. Of course, this requires machine time, manpower, and additional chemicals to restore the brushes resilience, factors that would better be spent on wafer production and that ultimately increase the costs of production of semiconductor wafers and chips.

Accordingly, what is needed in the art is an apparatus and method that requires minimal to no investment of technical manpower for maintaining cleaning brushes in a virtually constant state of readiness to clean semiconductor wafers.

SUMMARY OF THE INVENTION

To address the above-discussed deficiencies of the prior art, the present invention provides a method of manufacturing an integrated circuit using a cleaning brush and a cleaning brush conditioning apparatus. In one embodiment, the cleaning brush conditioning apparatus comprises a conditioning bar and a load cell coupled to the conditioning bar. The load cell is configured to force the conditioning bar against the cleaning brush.

In another embodiment, the conditioning bar is cylindrical and has a longitudinal axis and the conditioning bar is capable of rotating about the longitudinal axis. The conditioning bar, in other embodiments, may comprise a surface material of TEFLON® (i.e., synthetic resinous fluorine), silicon, silicon nitride, ceramic, or silicon carbide. In a particularly advantageous embodiment, the cleaning brush is a semiconductor wafer cleaning brush.

In an alternative embodiment, the cleaning brush conditioning apparatus further comprises a dispenser containing a cleaning agent. The dispenser is coupled to the conditioning bar and configured to deliver the cleaning agent to the cleaning brush. In a further aspect, the cleaning agent may be deionized water, ammonium hydroxide, dilute hydrofluoric acid, other suitable chemical solvents, or surfactants.

The cleaning brush conditioning apparatus, in another embodiment, may further comprise a resiliency or indentation sensor coupled to the cleaning brush and configured to sense a resiliency of the cleaning brush, and a controller coupled to the load cell and to the resiliency sensor. The controller is configured to activate the load cell when the resiliency is less than a nominal resiliency. In yet another embodiment, the load cell is capable of applying a variable force.

The foregoing has outlined, rather broadly, preferred and alternative features of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing or modifying other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGS. **1**A and **1**B illustrate end and side views of one embodiment of a cleaning brush conditioning apparatus constructed according to the principles of the present invention;

FIGS. **2**A and **2**B illustrate end and side views of an alternative embodiment of the cleaning brush conditioning apparatus of FIGS. **1**A and **1**B;

FIG. **3**A illustrates an end view of a second alternative embodiment of the cleaning brush conditioning apparatus of FIGS. **1**A and **1**B;

FIG. **3**B illustrates an enlarged view of the resiliency sensor and cleaning brush of FIG. **3**A; and

FIG. **4** illustrates a partial sectional view of a conventional integrated circuit that can be manufactured,with the assistance of a cleaning brush manufactured in accordance with the principles of the present invention.

DETAILED DESCRIPTION

Referring initially to FIGS. **1**A and **1**B, illustrated are end and side views of one embodiment of a cleaning brush conditioning apparatus **100** constructed according to the principles of the present invention. The cleaning brush conditioning apparatus **100** comprises conditioning bars **110** and load cells **120** coupled to the conditioning bars **110**. The conditioning bars **110** are shown proximate cleaning brushes **130** that may be comprised of polyvinyl alcohol (PVA) and used to clean the surfaces **145** of a semiconductor wafer **140**. In the illustrated embodiment, the conditioning bars **110** are rectangular in cross section and of a sufficient length **111** to extend along the length **131** of the cleaning brushes **130** and of sufficient width **112** to assure proper brush **130** rotation. Of course, one who is skilled in the art will readily conceive of other shapes possessing advantages for specific brushes. The cleaning brushes **130** rotate as indicated at arrows **133** while the load cells **120** exert forces **123** on the conditioning bars **110** and against the cleaning brushes **130**. The semiconductor wafer **140** may also be rotated as shown at **143**. For the purposes of this discussion, the term "load cell" includes mechanical, i.e. springs, levers, etc., hydraulic, or pneumatic devices. One who is skilled in the art will readily conceive of a variety of such devices capable of providing the necessary forces **123**.

Referring now to FIGS. **2**A and **2**B, illustrated are end and side views of an alternative embodiment **200** of the cleaning brush conditioning apparatus **100** of FIGS. 1A and 1B. In this embodiment, the cleaning brush conditioning apparatus **200** comprises conditioning bars **210***a*, **210***b* (collectively referred to as **210**), load cells **120**, and dispensers **230** containing a cleaning agent **235** proximate cleaning brushes **240***a*, **240***b* (collectively referred to as **240**) and the semiconductor wafer **140**. The conditioning bars **210** are cylindrical in shape, and mounted on their longitudinal axes **211** so as to revolve during conditioning. The conditioning bars **210** may comprise a surface material **212** of tetrafluoroethylene silicon nitride, ceramics, or silicon carbide. Tetrafluoroethylene is known as TEFLON®, which is a trademark of Dupont Corporation. Of course, other materials may also be advantageously employed.

The dispensers **230** are individually coupled to the conditioning bars **210** and configured to deliver the cleaning agent **235** to the cleaning brushes **240**. In one embodiment, the cleaning agent **235** may be delivered by gravity to a surface **213***a* of the conditioning bar **210***a* and to the cleaning brush **240***a*. The cleaning agent **235** may be deionized water, ammonium hydroxide, or dilute hydrofluoric acid. Of course, the exact cleaning agent **235** must be chosen by considering the debris expected and the production stage of the semiconductor wafer **140**, even to including a surfactant. The cleaning agent **235** may be delivered by pressure to a surface **213***b* of the conditioning bar **210***b* and to the cleaning brush **240***b*. In one embodiment, the cleaning agent **235** may be pumped through a hollow core **211***a* of the conditioning bar **210***a*. Alternatively, the cleaning agent **235** may be sprayed (not shown) onto surfaces **213**. The choice of cleaning agent delivery system will be governed by factors such as the material of the brushes, the location of the brushes, the composition of the cleaning agent, etc.

To condition the cleaning brushes **240**, cleaning agent **235** is delivered to the conditioning bars **210**, and the bars **210** are rotated **214** as shown. The semiconductor wafer **140** may also be rotated **143** or may simply be passed between the brushes **240**. Forces **123** are exerted by the load cells **120** to continually flex the brushes **240**, thereby causing the PVA, or other similar material, to be alternatively compressed and relaxed, thereby preventing the PVA from hardening.

Referring now to FIG. **3**A, illustrated is an end view of a second alternative embodiment **300** of the cleaning brush conditioning apparatus of FIGS. 1A and 1B. In this embodiment, the cleaning brush conditioning apparatus **300** comprises conditioning bars **310***a*, **310***b* (collectively referred to as **310**), load cells **320**, a dispenser **330** containing a cleaning agent **335**, a resiliency sensors **340***a*, **340***b* (collectively referred to as **340**), and a controller **350**. One who is skilled in the art will readily observe that the conditioning bars **310** are most effectively conditioning plates **310** that extend beyond the length (not visible) of the cleaning brushes, collectively **360**, in this embodiment. The conditioning plates **310** rotate about pivots **315***a*, **315***b*. The cleaning brush conditioning apparatus **300** is proximate cleaning brushes **360***a*, **360***b*, and a semiconductor wafer **370**. The dispensers **330** deliver the cleaning agent **335** to the cleaning brushes **360** as described above.

Referring now to FIG. 3B, illustrated is an enlarged view of the resiliency sensor **340***b* and cleaning brush **360***b* of FIG. **3**A. The resiliency sensors **340** are in contact with the cleaning brushes **360**, respectively, and are configured to sense a resiliency of the cleaning brushes **360**. The resiliency may be measured by sensing a deflection **341** of the sensor **340** as the cleaning brushes **360** are rotated. The sensor **340***b* is under pressure from spring **345***b* that exerts a minimal force to ensure continuous contact with the cleaning brush **345***b*. Of course, the sensors **340** may alternatively be configured to intermittently contact the brushes **360**, thereby taking periodic readings. Less resilient brushes **360**, e.g., as the brushes harden, cause the sensor **340** to deflect less than resilient brushes from a position of first contact. The deflection **341** of the sensor **340** is then sent to the controller **350** via sensing loops **343***a*, **343***b*. The controller **350**, in turn, directs the load cells **320** via feedback loops **325***a*, **325***b* to cause greater forces **323** to be applied by the load cells **320** when the resiliency is less than a nominal resiliency. Nominal resiliency may be defined as a deflection of n mm for a particular resiliency sensor **340**, where n may be empirically determined from cleaning brushes **360** that exhibit an acceptable particle removal efficiency. Of course, the controller **350** may be coupled to the load cells **320** and may also adjust the amount of force **323** exerted by the load cells **320**, that is, the amount of force **323** applied is adjustable as required by the condition of the brushes **360**. The controller **350** may also be coupled to the dispenser **330** so as to adjust the amount of cleaning agent **335** dispensed based upon the sensed resiliency.

Referring now to FIG. **4**, illustrated is a partial sectional view of a conventional integrated circuit **400** that can be manufactured with the assistance of a cleaning brush manufactured in accordance with the principles of the present invention. In this particular sectional view, there is illustrated an active device **410** that comprises a tub region **420**, source/drain regions **430** and field oxides **440**, which together may form a conventional transistor, such as a complementary metal oxide semiconductor (CMOS), positive channel metal oxide semiconductor (PMOS), negative channel metal oxide semiconductor (NMOS) or bi-polar transistor. A contact plug **450** contacts the active device **410**. The contact plug **450** is, in turn, contacted by a trace **460** that connects to other regions of the integrated circuit, which are not shown. A via **470** contacts the trace **460**, which provides electrical connection to subsequent levels of the integrated circuit.

Thus, a cleaning brush conditioning apparatus has been described that applies a cleaning agent to the brushes and applies a flexing force to the brushes to maintain a desired brush resiliency. The conditioning apparatus may also comprise a resiliency sensor and a controller that adjusts the amount of cleaning agent and the force applied to the conditioning bars.

Although the present invention has been described in detail, those skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

What is claimed is:

1. A method of manufacturing an integrated circuit, comprising:

polishing a semiconductor wafer;

cleaning the semiconductor wafer with a cleaning brush;

applying a conditioning bar to the cleaning brush to condition the cleaning brush; and

forming and interconnecting active devices on the semiconductor wafer.

2. The method as recited in claim **1** further comprising laser scribing the semiconductor wafer.

3. The method as recited in claim **1** wherein polishing includes chemical/mechanical polishing.

4. The method as recited in claim **1** wherein the conditioning bar is a cylindrical conditioning bar having a longitudinal axis, the conditioning bar capable of rotating about the longitudinal axis.

5. The method as recited in claim **1** wherein the conditioning bar comprises a surface material selected from the group consisting of:

Tetrafluoroethylene;

silicon;

silicon nitride; and

silicon carbide.

6. The method as recited in claim **1** further comprising dispensing a cleaning agent to the conditioning bar and to the cleaning brush.

7. The method as recited in claim **6** wherein dispensing includes dispensing a cleaning agent selected from the group consisting of:

deionized water;

ammonium hydroxide; and

dilute hydrofluoric acid.

8. The method as recited in claim **1** further comprising:

sensing a resiliency of the cleaning brush; and

engaging a load cell when the resiliency is less than a nominal resiliency, the load cell pressing the conditioning bar against the cleaning brush.

9. The method as recited in claim **1** wherein applying includes applying with a variable force.

* * * * *